UNCLASSIFIED

AD NUMBER

AD485852

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; Jun 1966. Other requests shall be referred to US Army Biological Center, Fort Detrick, Frederick, MD 21701.

AUTHORITY

BDRL, D/A ltr dtd 28 Sep 1971

THIS PAGE IS UNCLASSIFIED

AD

485852

TECHNICAL MANUSCRIPT 295

OBSERVATIONS ON BETA-PROPIOLACTONE VAPOR DECONTAMINATION

Robert K. Hoffman
Lee M. Buchanan
David R. Spiner

JUNE 1966

UNITED STATES ARMY
BIOLOGICAL CENTER
FORT DETRICK

DDC AVAILABILITY NOTICES

Qualified requesters may obtain copies of this publication from DDC.

Foreign announcement and dissemination of this publication by DDC is not authorized.

Release or announcement to the public is not authorized.

DISPOSITION INSTRUCTIONS

Destroy this publication when it is no longer needed. Do not return it to the originator.

The findings in this publication are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

U.S. ARMY BIOLOGICAL CENTER
Fort Detrick, Frederick, Maryland

TECHNICAL MANUSCRIPT 295

OBSERVATIONS ON BETA-PROPIOLACTONE VAPOR DECONTAMINATION

Robert K. Hoffman

Lee M. Buchanan

David R. Spiner

Physical Defense Division
COMMODITY DEVELOPMENT AND ENGINEERING LABORATORIES

Project 1C622401A072 June 1966

ABSTRACT

Although beta-propiolactone (BPL) is an effective vapor-phase decontaminant for enclosed areas, some problems have been encountered in its use. Adequate air circulation during BPL dissemination could eliminate most of these troubles. It is recommended that when decontaminating the ordinary building or laboratory the spray amount of BPL be changed from the initially suggested one gallon per 16,000 cubic feet of space to one gallon per 25,000 cubic feet. The use of aqueous BPL solutions and thermal-type generators is not recommended.

OBSERVATIONS ON BETA-PROPIOLACTONE VAPOR DECONTAMINATION

Beta-propiolactone (BPL) has been shown to be an effective vapor-phase decontaminant for the treatment of enclosed areas.[1-5] It is effective not only against bacterial spores and vegetative cells, but viruses and rickettsiae as well.[6,7] It has been widely used in this laboratory, and to a lesser extent elsewhere, since it was first reported by Hoffman and Warshowsky in 1958. During its years of use, various observations have been made concerning problems encountered in its practical application; these, we feel, are worth recording.

The main purpose of this paper is (i) to discuss some of the physical characteristics of the chemical, (ii) to point out their relationship to the problems encountered in BPL decontamination, (iii) to indicate means of avoiding the problems, and (iv) discuss BPL toxicity and means of detecting trace amounts.

Liquid BPL is a good organic solvent; because of this, problems are often encountered when decontaminating with the chemical. The main one seems to be the dissolution of paints, lacquers, and waxes on surfaces in the enclosure treated; other problems include the attack on some plastics and the occasional formation of a tacky residue for the most part, on horizontal surfaces. These problems are due to the liquid beta-propiolactone or an aqueous solution of it, but not to the vapor, and thus can be eliminated by proper dissemination of the chemical. The primary considerations in BPL decontamination are listed and discussed below.

A. BPL CONCENTRATION

A BPL air concentration of 1 to 1.5 mg per liter is sufficient to kill bacterial spores within minutes.[1] To obtain this amount of BPL in an enclosure, however, a considerably higher concentration must be disseminated.[2] Originally, it was suggested that when decontaminating an enclosure, one gallon of BPL be dispensed for each 16,000 cubic feet of space at 25 C. Assuming no wall adsorption of the chemical and 100% efficiency of the dispenser, the theoretical air concentration would be 9.6 mg BPL per liter (Table 1). However the vapor pressure of BPL at 25 C is only 2.1 mm Hg (Table 2), so the highest obtainable vapor concentration is 8.1 mg of BPL per liter of space. Thus it is evident that at this temperature, if one gallon of BPL is sprayed per 16,000 cubic feet of space, the amount will be above air saturation concentration and six or seven times the actual concentration required to kill spores.

TABLE 1. THEORETICAL AIR CONCENTRATION AFTER SPRAYING ONE GALLON BPL INTO VARIOUS VOLUMES

Volume, cu ft	Concentration, mg/liter
12,000	12.78
16,000	9.6
20,000	7.67
25,000	6.38
30,000	5.11

TABLE 2. VAPOR PRESSURE AND MAXIMUM CONCENTRATION OF BPL IN AIR AT VARIOUS TEMPERATURES

Temperature, C	Vapor Pressure, mm of Hg	Concentration in Air,[a] mg/liter
-10	0.12	0.5
- 5	0.22	0.9
0	0.34	1.4
5	0.50	2.0
10	0.74	3.0
15	1.05	4.2
20	1.49	5.9
25	2.10	8.1
30	2.90	11.1
35	4.05	15.2

a. Calculated from formula $PV = nRT$.

If excess BPL is sprayed into an area or the dispenser emits large droplets, the lactone can literally "rain out" on surfaces, leaving a liquid coating. Since the surrounding air is close to saturation, the evaporation rate will at best be extremely low; liquid will have more time to react with and dissolve surfaces such as paints and plastics, or to polymerize and leave a tacky residue. In an unsaturated atmosphere we found the rate of evaporation from a surface to be about 1.6% per minute at 25 C or, expressed another way, the half-life was 43 minutes. It should be emphasized that it is only the liquid BPL that deleteriously affects paints and plastics, or leaves a tacky residue. The vapor has not been shown to be deleterious to normally encountered materials when used at recommended concentrations and exposure times.

When partially polymerized BPL (less than about 93% purity) is sprayed, a noticeable residue is occasionally produced that is difficult to remove from surfaces. This problem is not encountered when BPL of higher purity is employed. If BPL is to be kept for a time before use it should be stored at refrigeration temperature to retard the formation of polymers.

Recent tests at this laboratory demonstrate that a smaller amount of BPL can be sprayed, i.e., one gallon per 25,000 cubic feet of space, and yet provide adequate decontamination. This yields a theoretical air concentration of 6.4 mg per liter of air, several milligrams below saturation level at 25 C, yet it is still four or five times more BPL than is required to sterilize. There are several reasons why it is necessary to disseminate more BPL than that required to decontaminate. A primary one is that some BPL will adsorb on walls, floors, and other surfaces. Sprayer inefficiency, with inadequate air circulation and building leakage, can also be factors, although these can be circumvented as discussed later.

B. TEMPERATURE

Temperature, of course, is a major factor in controlling the amount of BPL the air will hold. Table 1 lists the vapor pressures of BPL at various temperatures and the corresponding maximum BPL air concentration. It is evident that as the temperature is decreased the maximum BPL air concentration decreases rapidly. Therefore, if BPL is used to decontaminate an enclosure at low temperatures the amount sprayed and the spray rate should be decreased to prevent possible oversaturation. Furthermore, for each 10 C drop in temperature the chemical requires two to three times longer to kill the same number of organisms. This factor, too, should be considered. Thus it is recommended that for low-temperature decontamination of enclosures, less BPL be disseminated and a longer exposure time be allowed. On the other hand, it is possible to decrease the exposure time by raising the ambient temperature of the enclosure. Of even more importance is the fact that at the higher temperature BPL evaporates more rapidly and there is less chance for liquid deposition during dissemination.

C. RELATIVE HUMIDITY

The importance of having a relative humidity of 70% or higher when decontaminating with BPL vapor was clearly demonstrated by Hoffman and Warshowsky.[1] Often the humidity of a structure to be decontaminated is below the 70% minimum, and water must be sprayed to obtain the required level. Raising the RH is best done by injecting steam from an open autoclave or steam-line outlet, spraying water from a nebulizer or using a vaporizer. Air should be circulated during this procedure. Just wetting the surface with water from a hose has been found unsatisfactory for raising the RH of an enclosure to the needed 70%. When humidifying, care should be taken not to over-humidify the enclosure. It has been observed that water droplets hanging from a painted ceiling have absorbed sufficient BPL during decontamination to have a solvent action on the paint under the droplets. Once the humidity is raised in an enclosure it is best to continue adding water vapor slowly during the decontamination period. This can be done by cracking a steam valve or using one or more small vaporizers.

Hydrolysis of BPL vapor, even in the presence of a very high relative humidity, is not of major concern. Tests in this laboratory have revealed that the rate of hydrolysis of BPL in air at 100% RH is about one-half that in water. Specifically, BPL at 25 C in water has a half-life of 3.5 hours and in air at 100% RH the half-life is about 7 hours. At lower RH the hydrolysis rate would be even less. It is thus obvious that an enclosure cannot be rid of BPL in less than a day merely by raising and maintaining a high RH.

D. AQUEOUS BPL SOLUTIONS

An aqueous solution of BPL is often sprayed to raise the relative humidity and disseminate the BPL in one operation. It seems that once such a practice is started, it becomes routine thereafter to spray an aqueous BPL solution regardless of the relative humidity. At times during the summer the ambient relative humidity is high and under these circumstances the air can hold very little more moisture. If water is sprayed along with the BPL the air becomes oversaturated and fallout results. When this occurs some BPL will be carried out with the water, producing a deleterious BPL solution on surfaces.

Spraying BPL with water further complicates the problems of decontamination because the droplets that are disseminated by a generator will be a mixture of water and BPL. The vapor pressure of water is higher and it will evaporate first. The evaporation of the water droplets will have a cooling effect, so that more time will be required for the BPL to vaporize. This increases the chances for liquid particles to fall out and collect on a surface.

Because of these factors it is strongly recommended that aqueous BPL solutions not be employed in enclosure decontamination. If it is necessary to raise the humidity, the water should be sprayed separately.

E. AIR CIRCULATION

A major factor in BPL decontamination is adequate air circulation by fans or building recirculating systems during dissemination of the chemical. Because the vapor pressure of BPL is so low, air in the vicinity of the spray will be rapidly saturated unless constantly diluted with fresh air. Ideally, the dispenser should deliver only vapor; however, if used properly a nebulizer that disseminates small liquid droplets is also satisfactory. If the vapor-type dispenser is used, the air must be circulated constantly to prevent oversaturation leading to condensation and fallout of liquid. If the nebulizer-type dispenser is used, the air must be circulated more rapidly to prevent particle fallout and to permit sufficient time for evaporation. The BPL output rate of any type of dispenser must not be greater than the amount the recirculated air can hold. Actually, there must be a greater air circulation rate than spray rate because the recirculated air will be capable of holding less and less BPL as it becomes more concentrated during dissemination and recirculation. For this reason it is recommended that BPL be disseminated into an enclosure slowly over a longer period of time.

By calculation, if the dispenser output is 100 ml of BPL per minute, 500 cubic feet of air per minute are required to take up the BPL vapor without oversaturation at 25 C (Table 3). The same amount of BPL would require 690 cubic feet of air per minute to prevent oversaturation at 20 C. Since the air will gain more and more BPL vapor as it is recirculated during the dissemination period, the air circulation rate must be greater than 500 cfm at 25 C or 690 cfm at 20 C. As a rule of thumb, it is suggested that the amount of air circulated be twice the volume required to hold the amount sprayed. Thus, in the example cited above, at 25 C the air circulation rate should be about 1000 cfm. If the sprayer delivers 200 ml BPL per minute, the circulation rate should be 2000 cfm, etc.

In decontaminating large areas, the air should be recirculated throughout the structure, especially during BPL dissemination. This is not always possible without a built-in recirculation system, although in some structures the air could be recirculated by a system of fans. If the structure lacks a recirculating system and has many small rooms, a number of small dispensers should be set up throughout and fans employed to assure adequate distribution.

TABLE 3. MINIMUM AMOUNT OF AIR AT DIFFERENT TEMPERATURES REQUIRED FOR COMPLETE VAPORIZATION OF 0.0264 GALLON (100 ml) BETA-PROPIOLACTONE

Temperature, C	Air, cu ft
10	1350
15	970
20	690
25	500
30	367
35	266

F. GENERATORS

Spiner and Hoffman[3] initially stated that almost any commercial insecticide sprayer could be used to disseminate BPL if the chemical did not "rain out" or thermally decompose. A second look at the type of dispenser that is desirable is in order. As stated above, a generator that delivers BPL vapor only is most desirable. It is not advisable to use ordinary thermal-type generators because of their high operating temperature. BPL decomposes to some extent even at its boiling point (162 C). Thermal-type generators operate at considerably higher temperatures than the boiling point of BPL, so some decomposition will occur; the amount will depend on the temperature and exposure time.

An even worse situation develops when an aqueous solution of BPL is sprayed by a thermal generator because BPL hydrolyzes rapidly at high temperatures. For example, the half-life of BPL in water at 25 C is 3½ hours; at 75 C it is only 5 minutes. No data are available on the hydrolysis rate at 200 to 300 C, the lower temperature at which a thermal generator operates; however, it is obvious that the hydrolysis rates will be extremely high under these circumstances. For this reason aqueous BPL should never be sprayed with a thermal-type generator.

Little consideration has been given to the flash point of the chemical when using a thermal-type generator for BPL. By the open-cup method BPL has a flash point of 74 C. To the authors' knowledge, no fires have resulted from spraying BPL with a thermal generator, but this may have only been fortuitous.

In summary, the thermal-type generator cannot be recommended as a BPL disseminator. The nebulizer-type dispenser seems to be the most satisfactory for the purpose as long as the particle size is small, and the air is circulated at a sufficient rate to prevent oversaturation, condensation, and fallout.

G. BPL TOXICITY AND DETECTION

The carcinogenic activity of BPL has been reported by Walpole et al.,[8] Roe and Glendenning,[9] Palmes et al.,[10] and Karlson and Weed.[11] These investigators showed that frequent subcutaneous or topical applications of dilute BPL produced tumors in rats and mice. According to Karlson and Weed, however, BPL appears to be a weak carcinogen. Because it is a carcinogen, Spiner and Hoffman[2] recommended that repeated exposure to even subirritating doses be avoided. That same publication stated that the lowest concentration of BPL detectable by smell is about 0.05 mg per liter of air. No observable harm has come to any of our personnel accidentally exposed for a short time to doses sufficiently high to cause respiratory irritation and lachrymation. It is suggested, on this basis, that if unmasked personnel can enter an aerated area after using BPL, and no discomfort is experienced, the area is no longer toxic. In order that it not be necessary to rely upon human olfactory sensitivity, a Chemical Corps gas detection tube was found satisfactory for detecting trace amounts of BPL.[2] Tests in this laboratory show this tube to be very sensitive; in fact, it is capable of detecting as little as 0.004 mg of the lactone. Thus, if a one-liter air sample is taken, it is possible to detect a BPL concentration as low as 0.004 mg per liter; in a 250-cc sample the lowest detectable concentration is 0.016 mg per liter. We feel that if no blue color appears (with the addition of sodium hydroxide) in the tube after taking a one-liter sample in an aerated room following BPL decontamination, it is safe for personnel to re-enter, unmasked. We calculate that ten air changes, vented to the outside, will remove the BPL from a structure. A word of caution is necessary however; BPL does adsorb on surfaces from the vapor in air, and it may require a relatively long time to desorb. For this reason an area aerated by forced ventilation could show no detectable BPL by the tube method, but if the aeration is discontinued and the area is closed up, an irritating concentration of BPL might build up because of desorption from surfaces. To avoid this situation, aeration, even reduced if necessary, should be continued for a short period after reoccupying the enclosure.

In conclusion, it is apparent that adequate air circulation can be the major factor in eliminating many of the troubles encountered in BPL enclosure decontamination. It is recommended that, when decontaminating the ordinary building or laboratory, the spray amount of BPL be changed from the initially suggested one gallon per 16,000 cubic feet of space to one gallon per 25,000 cubic feet of space. The use of aqueous BPL solutions and thermal-type generators is not recommended.

LITERATURE CITED

1. Hoffman, R.K.; Warshowsky, B. 1958. Beta-propiolactone vapor as a disinfectant. Appl. Microbiol. 6:358-362.

2. Spiner, D.R.; Hoffman, R.K. 1960. Method for disinfecting large enclosures with beta-propiolactone vapor. Appl. Microbiol. 8:152-155.

3. Bruch, C.W. 1961. Decontamination of enclosed spaces with beta-propiolactone vapor. Amer. J. Hyg. 73:1-9.

4. Alg, R.L.; Harris, G.J.; Barbeito, M.S. 1964. Disinfection with beta-propiolactone. Soap Chem. Spec. 40:97-100.

5. Barbeito, M.S. 1966. Emergency disinfection of operating room and patient ward with beta-propiolactone. Hospitals 40:100-106.

6. Dawson, F.W.; Hearn, H.J.; Hoffman, R.K. 1959. Virucidal activity of β-propiolactone vapor: I. Effect of β-propiolactone vapor on Venezuelan equine encephalomyelitis virus. Appl. Microbiol. 7:199-201.

7. Dawson, F.W.; Janssen, R.J.; Hoffman, R.K. 1960. Virucidal activity of β-propiolactone vapor: II. Effect on the etiological agents of smallpox, yellow fever, psittacosis, and Q fever. Appl. Microbiol. 8:39-41.

8. Walpole, A.L.; Roberts, D.C.; Rose, F.L.; Hendry, J.A.; Homer, R.F. 1954. Cytotoxic agents: IV. The carcinogenic action of some monofunctional ethyleneimine derivatives. Brit. J. Pharmacol. 9:306-323.

9. Roe, F.J.C.; Glendenning, D.M. 1957. The carcinogenicity of β-propiolactone for mouse skin. Brit. J. Cancer 10:357-362.

10. Palmes, E.D.; Orris, L.; Nelson, N. 1962. Skin irritation and skin tumor production by beta-propiolactone (BPL). Amer. Ind. Hyg. J. 23:257-264.

11. Karlson, A.G.; Weed, L.A. 1966. Beta-propiolactone as used in sterilization of homografts not carcinogenic to mice. Mayo Clinic Proc. 41:24-28.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U.S. Army Biological Center Fort Detrick, Frederick, Maryland, 21701	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

OBSERVATIONS ON BETA-PROPIOLACTONE VAPOR DECONTAMINATION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

Hoffman, Robert K.   Spiner, David R.
Buchanan, Lee M.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1966	14	11

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 1C622401A07?	Technical Manuscript 295
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this publication from DDC.
Foreign announcement and dissemination of this publication by DDC is not authorized.
Release or announcement to the public is not authorized.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Biological Center Fort Detrick, Frederick, Maryland, 21701

13. ABSTRACT

Although beta-propiolactone (BPL) is an effective vapor-phase decontaminant for enclosed areas, some problems have been encountered in its use. Adequate air circulation during BPL dissemination could eliminate most of these troubles. It is recommended that when decontaminating the ordinary building or laboratory the spray amount of BPL be changed from the initially suggested one gallon per 16,000 cubic feet of space to one gallon per 25,000 cubic feet. The use of aqueous BPL solutions and thermal-type generators is not recommended.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification